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BUREAU OF ENTOMOLOGY

FOREST INSECT INVESTIGATIONS

REPORT ON STUDIES ON TREE SELECTION

BY

THE WESTERN PINE BEETLE.

By

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Box 3010,
Stanford University, Calif.
April 3, 1926

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INTRODUCTION

The emphasis in forest entomology is gradually shifting from the protection of mature and overmature timber to the protection of reproduction, second growth and the trees left for increment and reseedling on outover areas. The problem of saving the stand which will serve as the basis for the second cut on timber sale areas under management is of special importance at this time. It is this timber, which will be ready to harvest within the next 50 to 70 years, which is being depended upon to tide us over that critical period between the time when our virgin stands will have played out and the time when the well managed forests of the future are able to supply our timber needs.

That the insect loss is important on many of the outover areas cannot be doubted. Studies, by the writer, of twelve outover areas in California, showed that on some areas, at least, the loss from insects amounts to more than the increment. To reduce this loss we must know whether or not the western pine beetle, which causes most of the loss, shows a preference for certain trees and if it does, what the characteristics of these trees are. If this can be worked out we can hope for a material reduction in our insect loss on outover areas, by taking out in the first cut, all trees most susceptible to insect attack.

The selection of a tree for attack, by an insect, may be due to characteristics of the site on which the tree is located or to characteristics of the tree itself. Site characteristics will be discussed first followed by the consideration of the characteristics of the trees selected.

Tree selection, as used in this paper, is not intended to mean a conscious selection of certain trees by the insects. It has been found that trees having certain characteristics are more apt to be killed by the western pine beetle than trees lacking these characteristics. Whether this selection is due to tropisms, instincts or intelligence will not be considered here.

SITE DESCRIPTION.

The effects of site differences are very hard to determine due to the complex of factors. A start on this phase of the problem was made in 1934. Ten sample plots of one or two acres each, five of which had no insect loss and five of which showed heavy insect loss, from the western pine beetle, were studied comparatively. Two large areas of about four sections each, one with light and the other with heavy insect loss were also compared.

The results of these studies were not very clear cut but indicated the following:

The western pine beetle prefers open, pure yellow pine stands along ridges or in any exposed site. Fast growing yellow pine in dense stands, especially in mixture, on north slopes and in low moist situations such as along streams is least attractive to this insect.

Cascadel Area Study.

During the summer of 1925 this part of the study was continued on the Cascadel area of the Sierra N.E.

This area includes about four sections in the form of a basin with drainage and principal exposures to the southwest. The elevation is between 4,000 and 5,500'. The stand is fairly typical of the west slope yellow pine type with a small percentage of sugar pine, incense cedar and white fir at the higher elevations, on the north slopes and along the creeks. Oaks and alder are the principal hardwoods.

The plan was to map the area by sites and locate all of the insect killed trees according to these sites.

Survey method.

A three man crew was used. The writer ran the compass, paced distances, and did the mapping. Wagner and Morrow, Scientific Aids, located and marked all of the trees killed by B. brevicauda or other insects and made out records for each. The cause of death, diameter, height, crown class, crown size and shape and character of bark was taken for each tree.

A base line was run on two opposite sides of each section with compass and chain. On this base line points were established every 10 chains. Using these points as controls strips 10 chains in width were run across each section until it was completed. The accompanying map shows the amount of detail secured. On the original map all of the insect killed trees were located as found and the whole area laid off in $2\frac{1}{2}$ acre squares.

The Forest Service site classification was used. This is based on the height of the highest 10% of the dominant trees. It is applicable to mature stands only. The site classes are as follows:

Site I	over 175'
" II	150 - 175
" III	125 - 150
" IV	100 - 125
" V	less than 100.

Estimation of acreage and insect loss for each site.

The area in each site was determined by the use of the $2\frac{1}{2}$ acre squares. While this method is not as accurate as the use of the planimeter would be it is as accurate as the mapping and so satisfactory for this purpose.

The number of insect killed trees was totaled by sites.

The following table compares the insect loss and acreage on three sites:

Table 1.
Insect Loss by Sites with Acreage

Site	Insect loss (No. of Trees)		Area (No. of Acres)	
II	31	7.4% of total	257	14.5% of total
III	252	60.3 " "	1,057	58.5 " "
IV	115	27.5 " "	350	20.0 " "

The results are shown graphically on Plate I.
Practically all of the insect killed trees were killed by D. brownianis.

The site V area was not included because the yellow pine stand was so thin that it could not be compared with the other areas.

It is evident that taking Site III as the average the better sites have less insect loss and the poorer sites have more insect loss for the same acreage.

However, this does not prove that the western pine beetle prefers the poorer quality site itself. Since the trees are slower growing on these poorer sites it may mean only that the beetles prefer the slow growing trees.

TREE SELECTION

The tree characteristics studied are divided into, (a.) external characters such as the size and shape of the crown and the diameter and height of the tree; and, (b.) vigor as shown by the width of the annual ring.

External Characters.

Crown class, size, and shape.

About 200 yellow pine killed by the western pine beetle were marked on the Caspabel area in 1925. They were all classified as is shown in the following table:

Table 2.
Crown classification and Number of Trees in Each Class.

Crown class-	No. of trees.
Dominant	60
Co-dominant	103
Intermediate	31
Suppressed	2
Crown shape-	
Pointed	0
Rounded	175
Flat topped	25
Crown length-	
Long	7
Medium	167
Short	29
Crown width-	
Wide	7
Medium	171
Narrow	24

As it is not known what percentage of the total stand is in each of these classes it is impossible to draw definite conclusions as to the classes preferred by the beetles.

It is evident, however, that the average tree of dominant and co-dominant crown class with rounded top and medium length and width of crown suffers the heaviest loss. It is surprising that the number of intermediate and suppressed trees killed is so small. This is probably due to the fact that the total number of such trees in the stand is small because of the openness of the stand.

The fact that no trees with sharp pointed crowns, denoting a fast growing tree, were killed is significant. The number of trees with flat topped crowns, killed, is probably high in proportion to the total number in the stand.

Diameter of trees selected.

The diameter selection of the western pine beetle is more easily demonstrated. By comparing the distribution by diameter curve for the total stand with the same curve for the D.b. killed trees the preferred diameters become apparent. The D. b. killed tree curve on Plate II is based on 336 trees killed by D. b. on the Cascaded area. The total stand curve was prepared by Sanford, formerly Forest Examiner on the Sierra N.F., from some thousands of trees marked in cruising on the Sierra.

Plate III compares the distribution by diameters of over 5,000 D.b. killed trees from the entire San Joaquin Project area with the diameter distribution of the total stand. The total stand curve is the same as that used for Plate II.

It is apparent from these curves that the number of trees killed in the diameter classes between 20 and 30 inches is much greater than proportionate to the number of such trees in the total stand.

Evidently the western pine beetle prefers trees between 20 and 30 inches in diameter.

Height of trees selected.

No actual comparison of heights of insect killed trees with the total stand heights has been made. This could be done and would probably prove to be worth while.

Since the sites in the Cascadel study were classified purely on the height basis we have an indication in the fact that the highest proportionate losses were on the sites having the shortest trees. General observations support this belief. Then too, diameter growth and height growth are both indicative of the vigor of a tree. It will be shown later that D. brevicornis usually selects the slower growing trees. Therefore, it is reasonable to suppose that it also shows a preference for the shortest trees.

Vigor of Trees Selected.

Vigor is a more or less intangible character and is not used directly. The width of the annual rings has been used in this study as an index of vigor. It is realized that ring width alone is not always a true index but it is used because it is the most easily determined character and because it is believed that it is the most reliable single character that could be used for the purpose intended.

For a number of reasons vigor or ring width has been emphasized more than any of the other factors in this study. It is most important from a foresters standpoint especially if it can be shown that the slowest growing trees are selected; and it is a definite character that can be easily compared in insect killed trees and living check trees; it is possible to collect enough data on this point to make the results of importance.

The basic idea of the study is as follows:- If, of two trees of the same size and located on the same site, the slower growing one is killed by the beetles in a high proportion of cases, they (the beetles) must show a preference for the slower growing trees.

The field work consisted in taking increment cores from a large number of D.b. killed trees and from a living check tree, of the same diameter and site, for each D.b. killed tree.

A Swedish increment borer was used for taking the cores.

In all, cores from over 1,000 D.b. killed trees and from about an equal number of living check trees have been taken and measured. A great many more cores have been collected but have not yet been measured.

The cores used were taken from a number of areas in California and Southern Oregon. A. Wagner, E. Morrow, and E. Buckhorn, Scientific Aids, assisted in the work of taking and measuring the cores.

The instrument used in measuring the cores is called the increment core comparator. Roughly this device consists of a steel frame 5" x 2 1/2" with a sliding stage operated by a micrometer screw with a dial 2" in diameter at one end. On the circumference of this dial are gradations to 1/100 of a millimeter. By means of a friction screw it is possible to set the dial at zero for each measurement. To adapt this comparator to our use a brass clamp for holding the cores was fitted to the sliding stage by J.B. Patterson. This was so made that about 1/6 of the core projected above the clamp. When in use this part of the core was shaved off to produce a smooth surface and so increase the accuracy of the measurements. This comparator was then fitted firmly to the stage of a binocular microscope and used with a cross hair disc in one of the eye pieces.

The core, clamped to the sliding stage, is moved passed the cross-hair by turning the dial on which is recorded, as with a vernier, the distance moved, in this case the width of the ring being measured.

For a drawing of this instrument see the Western Division News Letter for February, 1925.

The data taken for each core include the width of each of the last 5 to 10 rings, the number of rings in the last inch and the diameter of the tree from which the core was taken.

The data have been worked up under four different headings all of which help to prove that D. brevis selects the slower growing trees, but that this selection is more definite under one set of conditions than under another.

1. Percentages of cases in which the trees killed by D.b. are growing (a) slower than, (b) faster than and (c) the same as the living check trees.

The growth rate of each D.b. killed tree was compared directly with that of its living check of the same size and site.

Table 2 shows a comparison of 81 pairs of cores from the Cascade area. All of the D.b. trees were killed in 1924. The difference between using the number of rings in the last inch and the width of the last two rings preceding the year when killed is shown.

Table 2.
1924 - Cascade Cores
Using 1922 Rings
and 1923 "

	Rings in last inch.		Rings in last inch.	
	No. of pairs -	%	No. of pairs -	%
a. D.b. Killed - Slower growing	69	85%	59	73%
b. " " " - Faster	7	9%	15	18%
c. No difference	5	6%	7	9%
	81	100%	81	100%

It is evident that the beetles showed a definite selection of the slower growing trees. This table also shows that the number of rings to the last inch should not be used as an index to the rate of growth just preceding the date of killing. Since the last two rings show what the tree is doing at the time it is attacked it is the best basis and will be used in the other tables. Some of the trees have over 100 rings to the last inch while the average of the cores taken from the D.b. killed trees is about 35. Obviously it is more important to know what the tree has been doing for the last two years than to know what it was doing 30 or 40 years ago.

Table 3 is based on 76 pairs of cores from the Cascadel area. The D.b. trees were all killed in 1925.

Table 3.
1925 - Cascadel Cores

	No. of Pairs - %	
D.b. Killed - slower growing	42	55%
" " " - faster growing	19	25%
No difference	15	20%
	<u>76</u>	<u>100%</u>

The selection of the slow growing trees is much less definite for the trees killed in 1925. This difference is also shown in Tables 4 and 5 based on southern Oregon cores and the Happy Camp unit of the Modoc N.P. respectively.

Table 4.
1924 - Southern Oregon Cores

	No. of Pairs - %	
D.b. Killed - slower growing	250	75%
" " " - faster growing	50	15%
No difference	25	10%
	<u>325</u>	<u>100%</u>

Table 5.
1925 - Modoc - Happy Camp Cores.

	No. of Pairs - %	
D.b. Killed - slower growing	15	65%
" " " - faster	5	25%
No difference	2	10%
	<u>22</u>	<u>100%</u>

To the writer the most reasonable explanation for the fact that more of the faster growing trees were killed in 1925 than in 1924 is as follows:

1924 was the first year of the severe epidemic conditions and the large number of trees killed was probably the result of unusually favorable conditions for the beetles. The supply of favorable host material, slow growing trees, was large and the weather conditions were favorable, a long warm season with about $\frac{1}{2}$ normal precipitation. It was noticeable during the control work in Chiquito Basin that only a few beetles, comparatively, were required to kill many of the trees. Patterson found, also, that the brood mortality in southern Oregon was low in 1924. As there was a good supply of favorable host material the beetles followed their natural tendencies and selected the slow growing trees.

These conditions bred up such a large number of beetles that there was less chance for selection, the beetle population was abnormally high and the number of slow growing trees was low because of the large numbers killed in 1924. This caused the beetles to attack and kill, by force of numbers, many fast growing trees which they would not otherwise have selected. But in overcoming the resin flow of the fast growing trees, they must have sacrificed themselves in such numbers that the force of the epidemic was probably broken. This would lead us to expect a lower infestation in 1925, under normal conditions. A very dry spring in 1926 might overcome this tendency and give us another heavy insect loss in 1926.

Table 6 is a summary table for all the cores compared. They are from the Cascade area, the southern Oregon area, and the Modoc - Happy Camp area. Both 1924 and 1925 killed trees are included with their checks.

Table 6.
Cascade, So. Oregon and Modoc Cores.

	No. of Pairs - %	
D.b. killed slower growing	374	73%
" " " faster growing	61	12%
No difference	57	11%
	512	100%

With 512 pairs of cores from three different areas showing such a definite preference it is safe to assume that in the majority of cases the western pine beetle selects the slower growing trees. This preference varies in degree under different conditions and especially according to the status of the infestation.

2. Comparison of average growth rate of D.b. killed trees and their living check trees.

Under this heading the growth rate of the trees killed by D.b. is compared with the growth rate of living check trees of the same size and site. The width of the annual ring is used as indicative of growth. The tables are based on the average ring width of all the trees used for 1920 ^{to} 1924.

Plate IV shows a comparison of the ring width of the D.b. trees killed in 1924 and their checks with the D.b. trees killed in 1925 and their checks. This shows in another way the same points brought out in Tables 1 to 4. While the beetles show a preference for the slow growing trees this preference is less definite in 1925 than in 1924.

Plate V-1 compares all of the D.b. killed trees on the Cascal area with their checks and Plate V-2 compares the growth rate of 400 D.b. trees killed on the southern Oregon area in 1924 with their green checks. A very decided preference for the slower growing trees is shown in both of these graphs.

Plate VI shows this same preference for three different areas. The cores on which these graphs are based were collected and measured in 1924 with the old type of measuring device on which the measurements were made in 1/100 inches instead of millimeters.

It will be noticed that on the California area the growth rate of the trees killed during the epidemic of 1923, when the infestation increased 700% in one season, is higher than that for trees killed during endemic or normal conditions. This is to be expected since a large number of beetles, striking an area and killing the trees in large groups by force of numbers would naturally be less selective than a small number of beetles killing a tree only here and there.

3. Comparison of the growth rate of D.b. killed trees with their living checks at each 4" diameter class.

Mr. Miller suggested that the preference of the beetles for the slower growing trees might be limited to certain diameters. To determine this the cores were divided into 4" diameter classes and the ring width of the D.b. killed trees was compared with the ring width of their checks in the same diameter class. The graphs were plotted in two ways, using the average ring width for each group and also using the mean. The results were about the same in both cases but the mean is used in the graphs given here because it gives a little smoother curve, and is probably a little more accurate.

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The results are given on Plate VII. While the beetles show a preference for the slower growing trees at all diameters this preference is a little more pronounced at some diameters than at others. The difference in the curves for the two areas is also interesting but no explanation can be offered.

4. Distribution by growth rate of D.b. killed trees compared with their living checks.

On Plate VIII the curves for the D.b. killed trees of 1924 are compared with those of 1925, on the Cascadel area.

Plate IX is based on cores from southern Oregon areas, and Plate X on outover areas of California.

Plate XI is a summary of all the areas based on all the cores measured to date, 1,033 from D.b. killed trees and 903 from living check trees.

These curves complete the evidence presented to show that the western pine beetle, in some way unintelligible to us, is able to and in the majority of cases does select the slowest growing yellow pine for attack. Referring to Plate XI it is found that while nearly 45% of the D.b. killed trees were putting on a radial growth of less than .2 millimeters ~~only~~ only about 17% of the living check trees were growing this slowly.

Application to Forest Management

These curves should be of interest to foresters. Plate XI shows that 91% of the yellow pine killed by the western pine beetle on areas in California and southern Oregon were putting on an annual ring less than 1 millimeter in thickness, which means that the diameter increase is less than 2 millimeters. It is obvious that the increment on such slow growing trees is of little value. The fact that the trees of least value for increment also constitute the greatest risk from insect loss is an encouraging feature. If it is possible to so improve the marking methods that all of these slow growing trees can be taken out in the first cut it is believed that the insect condition on outover areas will be materially improved.

THE IMPORTANCE OF TREE RESISTANCE

The theory has been advanced that the beetles attack indiscriminately but are able to kill only the slow growing trees which offer the least resistance in the way of resin flow. This view is hardly tenable since in spite of the great amount of crusting that is done very few trees are found which have been unsuccessfully attacked. At certain times, however, when the number of beetles on an area is too great for the number of slow growing trees the resistance of the fast growing trees is an important factor in reducing the infestation. A much large number of beetles are required to overcome the resin flow of the fast growing trees and this concentration often causes crowding of galleries and a consequent high brood mortality.

TREE SELECTION BY OTHER FOREST INSECTS

All the data presented in this paper deals with the selection of yellow pine by the western pine bark beetle. It is evident from preliminary studies on other forest insects that the western pine beetle represents the exception rather than the rule in showing a preference for the slow growing trees.

The mountain pine beetle (*D. monticolae*) in Sugar Pine.

Mr. Miller compared the growth rate of 58 sugar pine killed on the Ellis Meadow area of the Sierra N.P. with the growth rate of living check trees and found that no preference was shown for the slow growing trees.

The engraver beetle (*Ips confusus*) in yellow pine.

Cores were taken from about 50 Ips topkilled trees and the same number of living check trees from the Cow Creek area of the Stanislaus N.P. and from the Lake Arrowhead area of the San Bernardino N.P. by the writer. No selection of the slow growing trees was found.

The Black Hills beetle (*D. ponderosae*) in yellow pine.

Mr. F. P. Koen studied the cores from a large number of yellow pine killed by the Black Hills beetle on the Kalihab Plateau and compared their growth rate with that of living check trees. He found that what little preference was shown was for the fast growing trees rather than for those that were slow growing.

SUMMARY

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1. The loss caused by the western pine beetle is an important problem on many of the outer areas of California and southern Oregon. To reduce this loss it is important to know whether or not this insect shows a preference for certain trees, and if it does what the characteristics of these trees are.

2. The selection of a tree, by an insect, may be due to characteristics of the site on which the tree is located or to characteristics of the tree itself.

3. In general, the poorer sites with open, pure yellow pine stands along ridges or on any exposed location are preferred by D. brevicornis.

4. A study on the Cascadel area of the Sierra N.F. showed that the loss from D.b. per unit area varied inversely with the quality of the site, the heaviest losses being found on the poorest sites.

5. The relation of crown class and shape to selection by D.b. has not been satisfactorily determined due to lack of sufficient data as well as a probable lack of any definite relation.

Trees with sharp pointed crowns, denoting fast growth, are practically free from attack.

Some preference was shown for trees with flat crowns.

No preference for trees in the intermediate and suppressed crown classes was evident.

6. A decided preference for trees between 20 and 30 inches in diameter is shown.

7. The western pine beetle probably prefers the shorter trees.

8. The western pine beetle shows a definite selection of the slower growing trees. Over 1000 increment cores from D. b. killed trees and an almost equal number from living check trees of the same site and size were studied comparatively to prove the following points:

a. The D.b. killed tree was growing slower than the living check tree in about 75% of the cases compared.

b. The average growth rate of the D.b. killed trees was about 40% less than the growth rate of the living check trees.

c. The preference of D.b. for the slower growing trees is definitely shown for all diameters, though this preference is more pronounced at some diameters than at others.

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d. Distribution by growth rate curves for D.b. killed trees and the living check trees show that --

While nearly 45% of the D.b. killed trees showed a diameter growth of less than .4 millimeters a year, only 17% of the checks were growing that slowly.

91% of the D. b. killed trees showed a diameter growth of less than 2 millimeters annually.

9. The preference of D.b. for the slow growing trees varies in degree with the area and the status of the infestation. It is believed that the preference is more marked under endemic or increasing epidemic conditions than under decreasing epidemic conditions.

10. The slow growing trees which are of least value for producing wood are the trees most likely to be killed by the western pine beetle. If these trees can be taken out in the first cut the condition of the cutover areas will be materially improved from the standpoint of both insect damage and growth rate.

11. D. hirsuticornis rarely attacks trees that it is not able to kill.

During decreasing epidemic conditions attacks on fast growing trees results in a high mortality both in the attacking beetles and in the broods, due to crowding. These are important factors in the reduction of the infestation.

12. Preliminary studies on the mountain pine beetle, the Black Hills beetle and an engraver beetle by Miller, Keen and the writer, respectively, indicate that the western pine beetle is the only important western forest insect that shows a definite selection of the slow growing trees.

SUGGESTIONS FOR FURTHER STUDIES

1. Studies should be made to determine the growth rate of the tree at the time of attack. It is evident that a tree which is fast growing during the spring attack might be very slow growing during the summer or fall attacks. Whether this actual growth rate of the tree at the time of attack or the relative vigor of the tree based on the growth rate for the year is the important factor should be determined.

The use of the dendrographs on three or four trees during the season together with aging experiments to determine the resistance of different trees will help in the solution of this problem. A study of the D.b. killed tree records to determine the time of year in which the slow growing and fast growing trees were killed will also be worth while.

2. A comparison of the average growth rate for the entire Cascadel stand with the growth rate of the trees used as check trees against the D.b. killed trees will be of value.

This will eliminate the site factor in comparing the D.b. killed trees with the living trees. Under the present method the checks are all located on sites which have some insect loss.

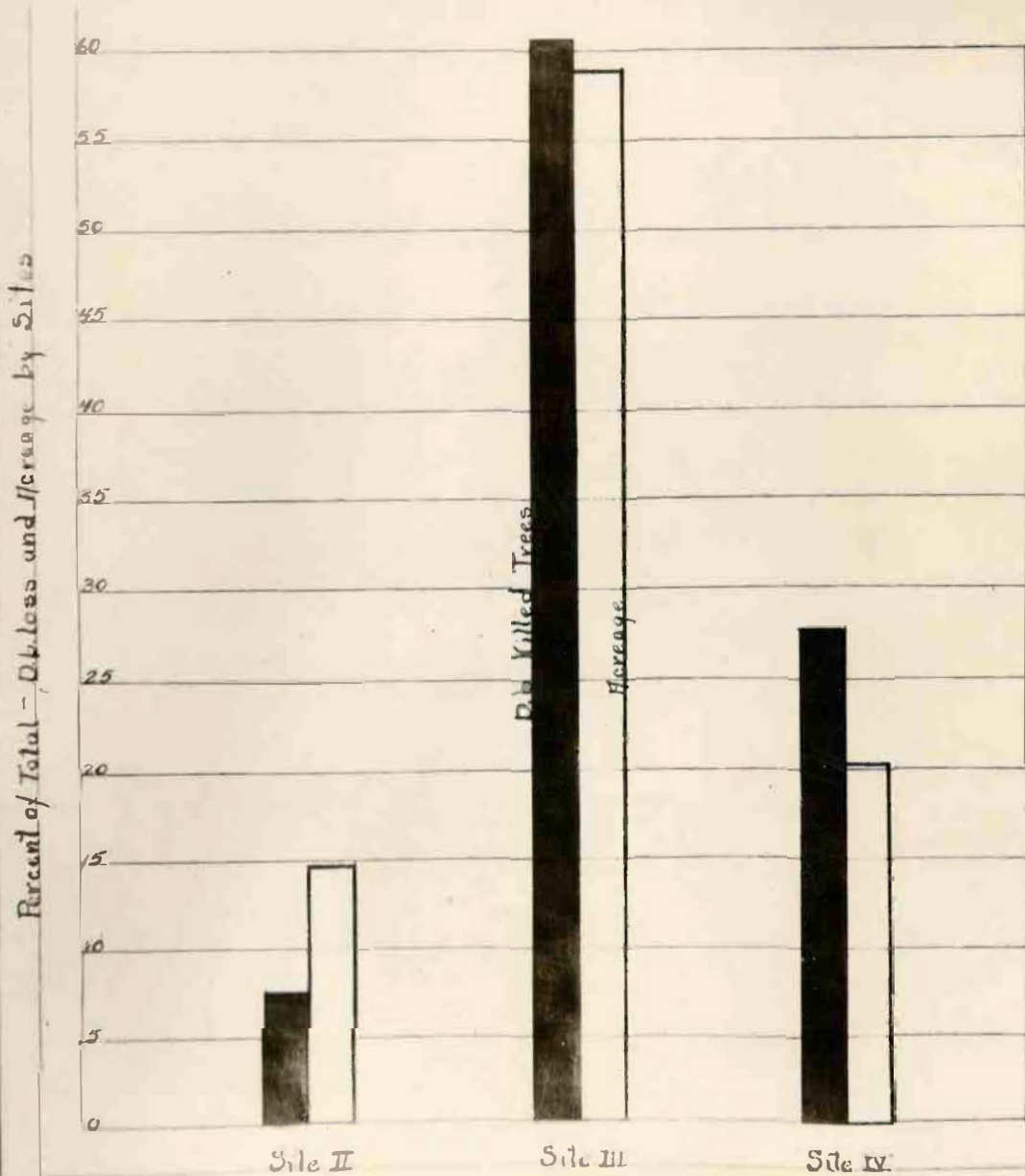
This study will require the taking of a large number of cores from mechanically selected green trees throughout the Cascadel area.

3. A test of the application of these studies is planned in co-operation with the Forest Service.

Areas will be selected which will be logged within the next year if possible. One area will be marked so as to take out all trees considered susceptible to insect attack. Another area will be marked according to present marking methods and used as a check. The insect loss on these areas will be determined ^{for} ~~for~~ a number of years.

PLATE I

Number of *Dbravicomis* Killed Trees and Average
by Sites - Gossadal Area



H.L. Person

PLATE II

Distribution by Diameter Curves - Cascadel Area

Solid line — *D. brevicornis* Killed Trees (336 Trees)

Dotted line — Total Stand Curve

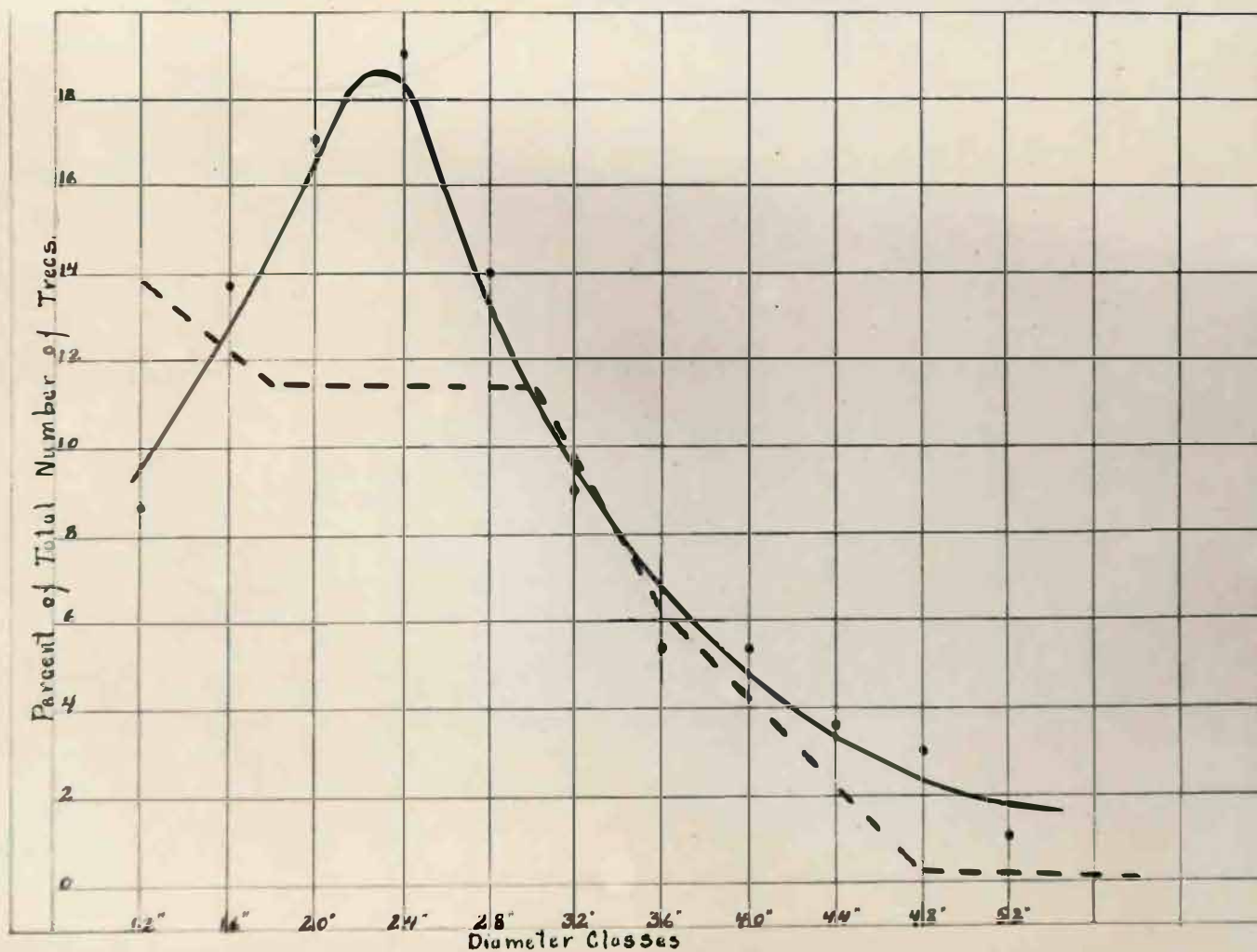


Plate III

Distribution by Diameter Curves - San Joaquin Project Area

Dh —

Total stand - - - -

PLATE IV - 1.

Comparative Growth Rate of D.b. Killed Trees and Living Trees
Cascadel Area - D.b. Trees Killed in 1925

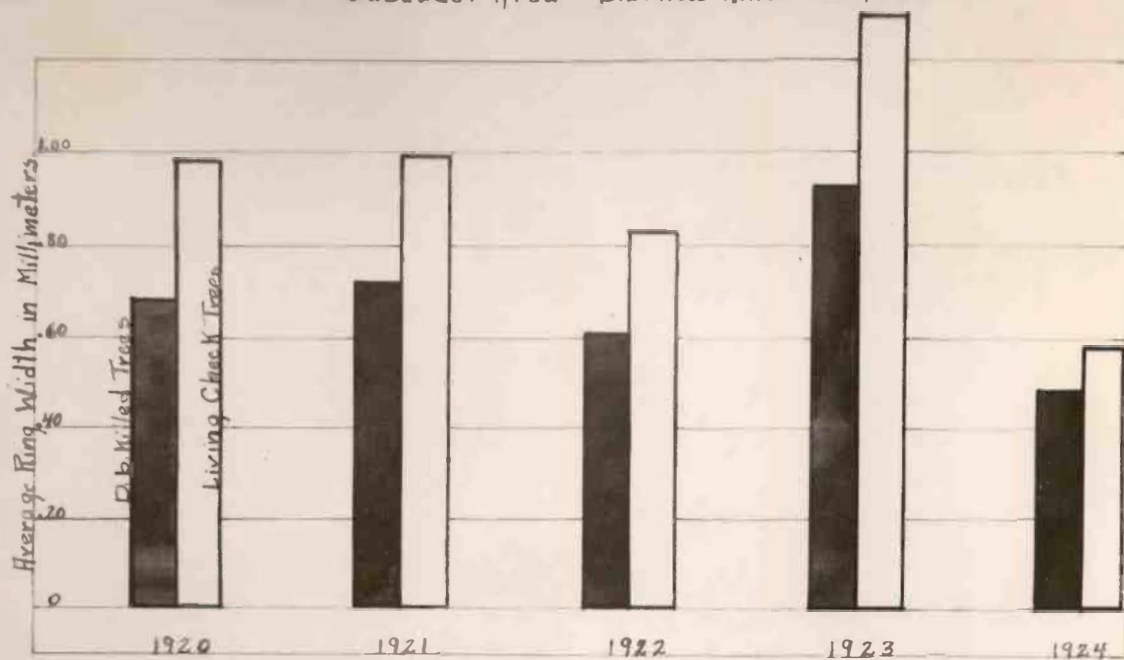


PLATE IV - 2.

Cascadel Area - D.b. Trees Killed in 1924

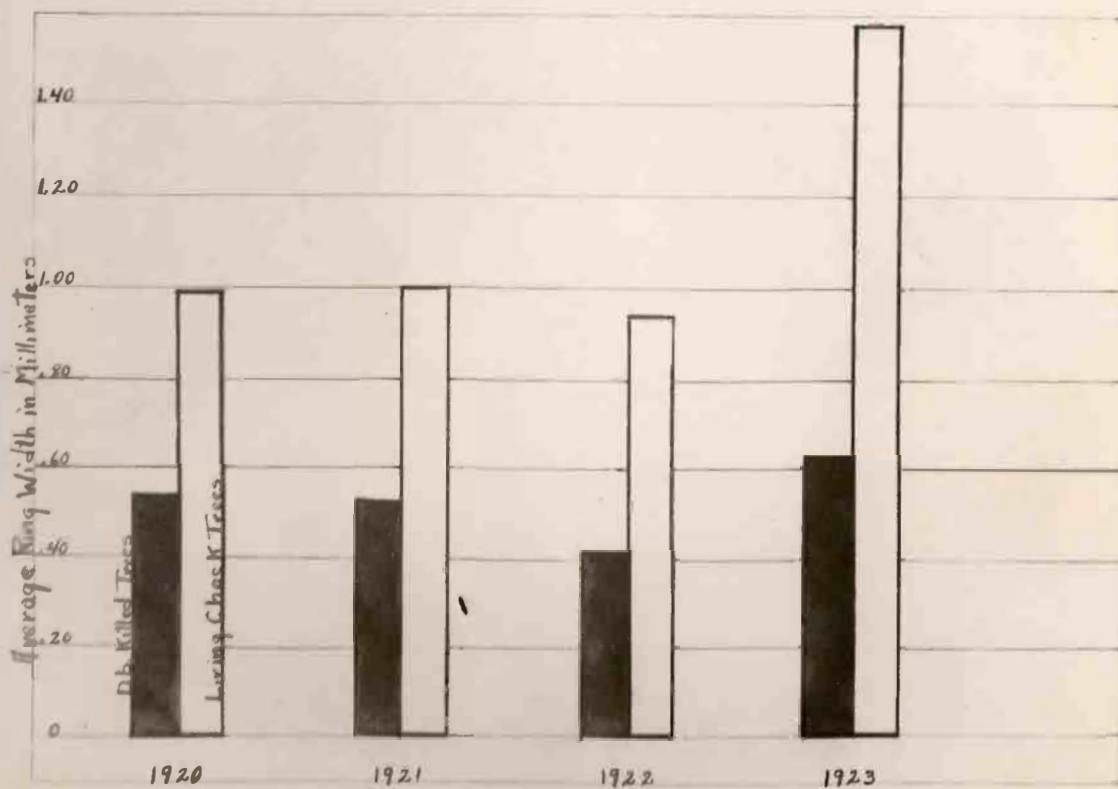


PLATE V-1.

Comparative Growth Rate of D.b. Killed Trees and Living Trees
Cascadel Area - D.b. Trees Killed 1924 & 1925

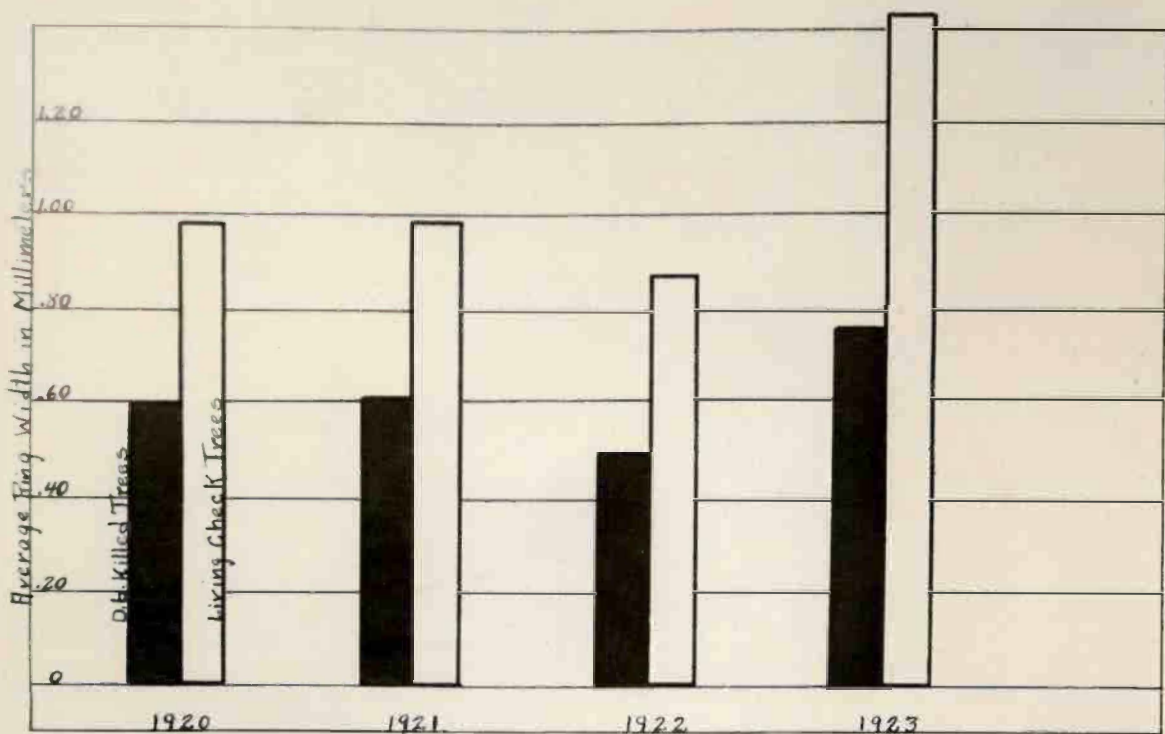
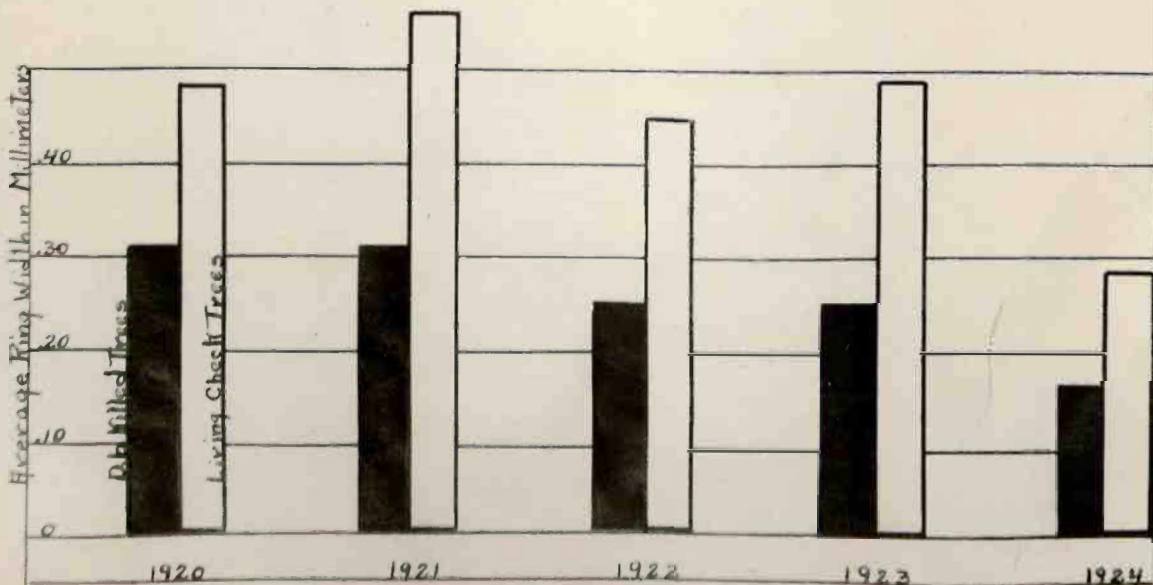


PLATE V-2

Southern Oregon Area - D.b. Trees Killed 1924
Basis - 800 Cores.



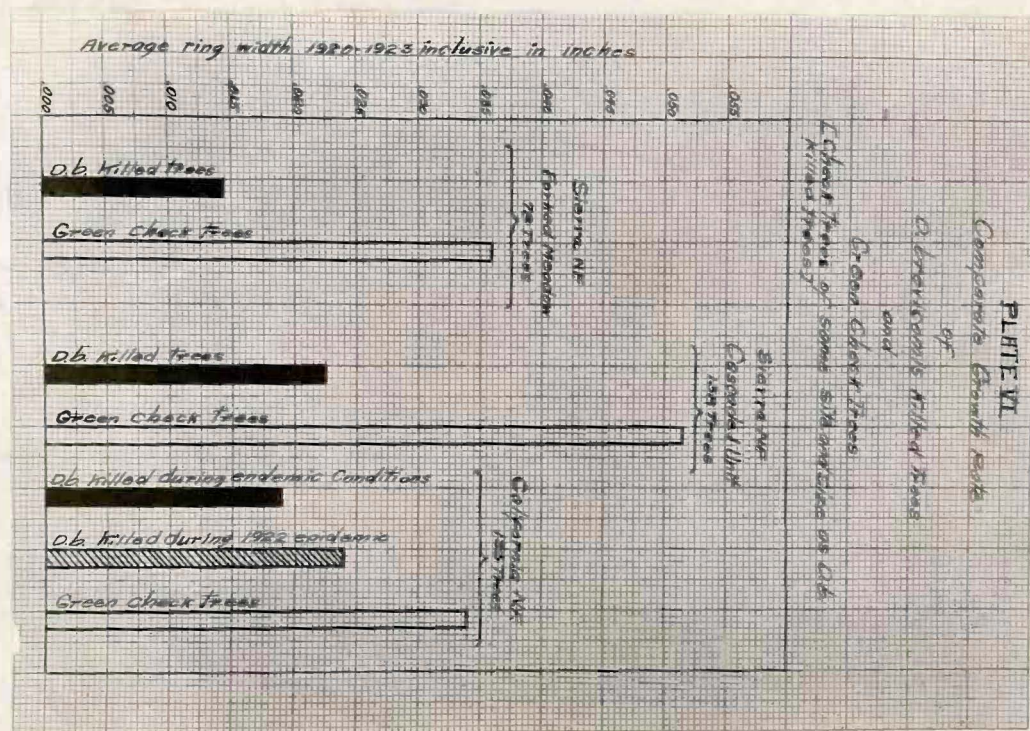


PLATE VII - 1.

Comparison of Growth Rate of D.b. Killed Trees and Living Trees
by Diameter Classes.

So. Oregon Area - D.b. Trees Killed 1924

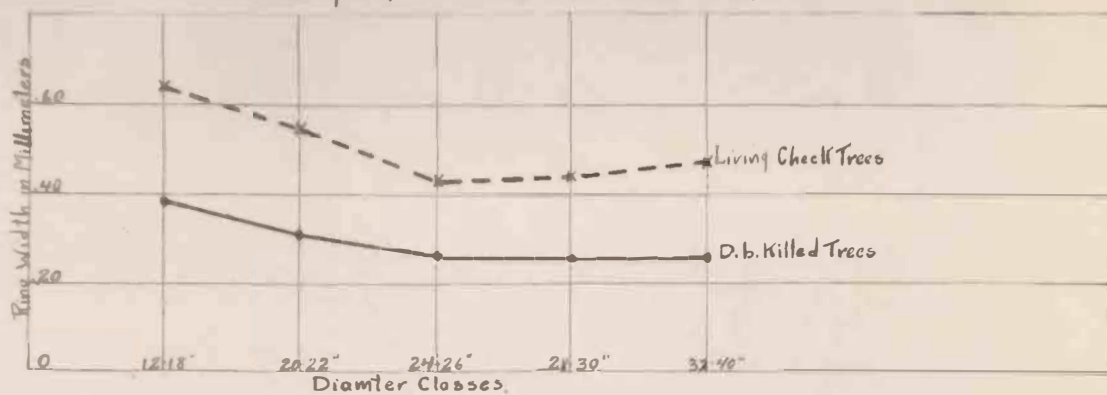


PLATE VII - 2

Cascadel Area - D.b. Trees Killed 1924 & 1925

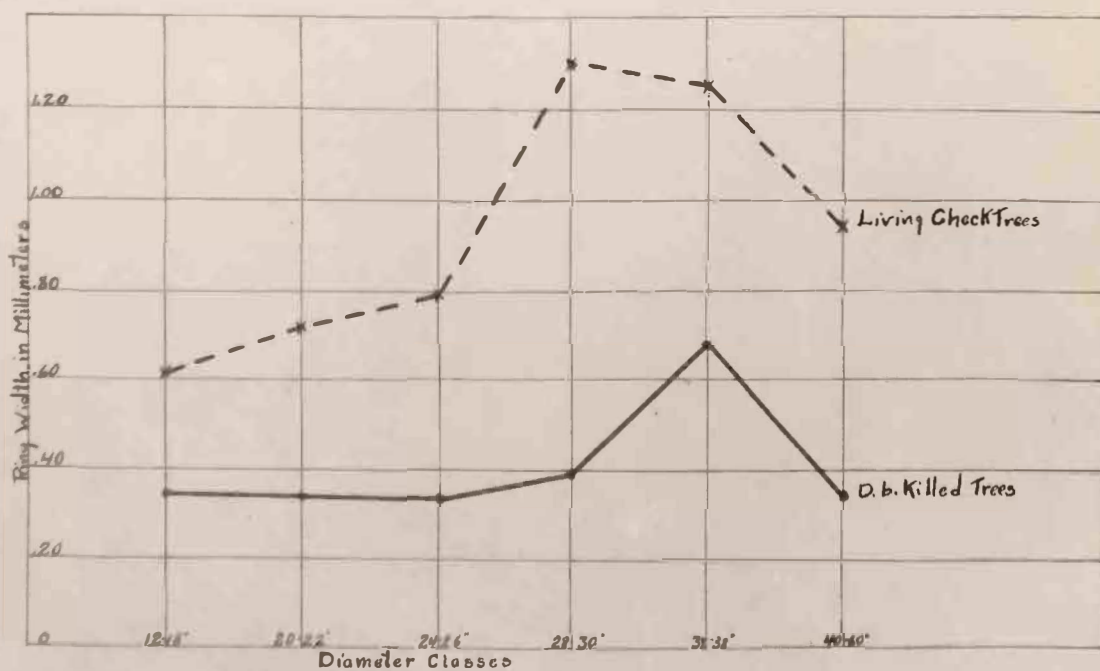


PLATE VIII - 2.

Distribution by Growth Rate of D.b. Killed Trees & Living Check Trees.

Cascadel Area - D.b. Trees Killed 1925 Basis - 189 Cores.

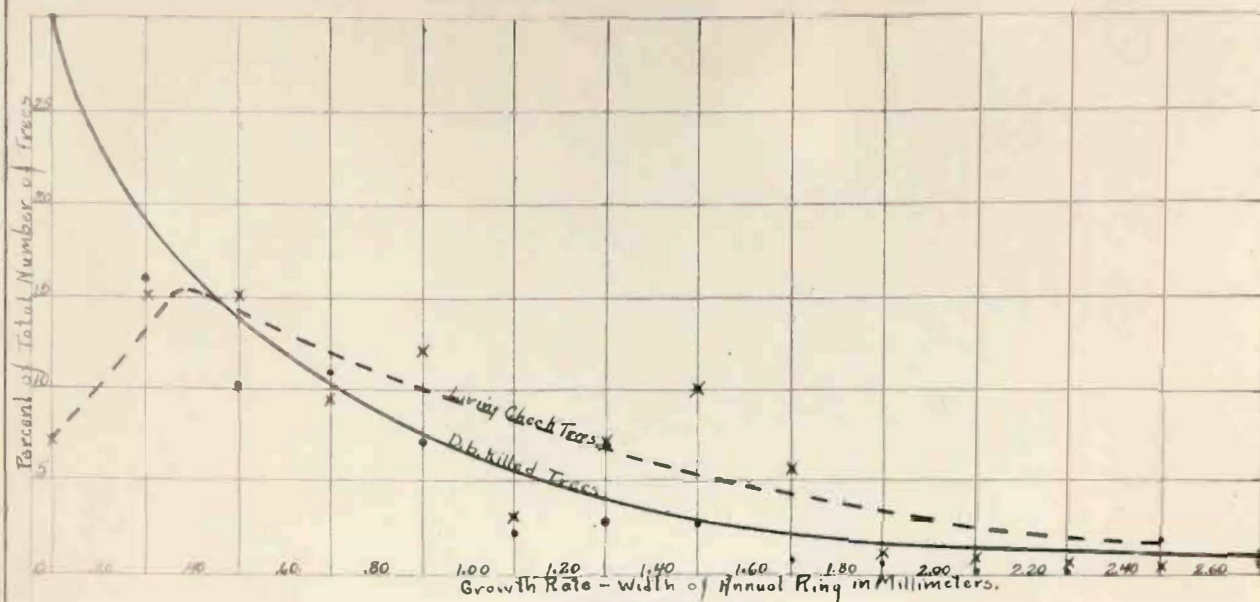


PLATE VIII - 1.

Cascadel Area - D.b. Trees killed 1924. Basis - 162 Cores

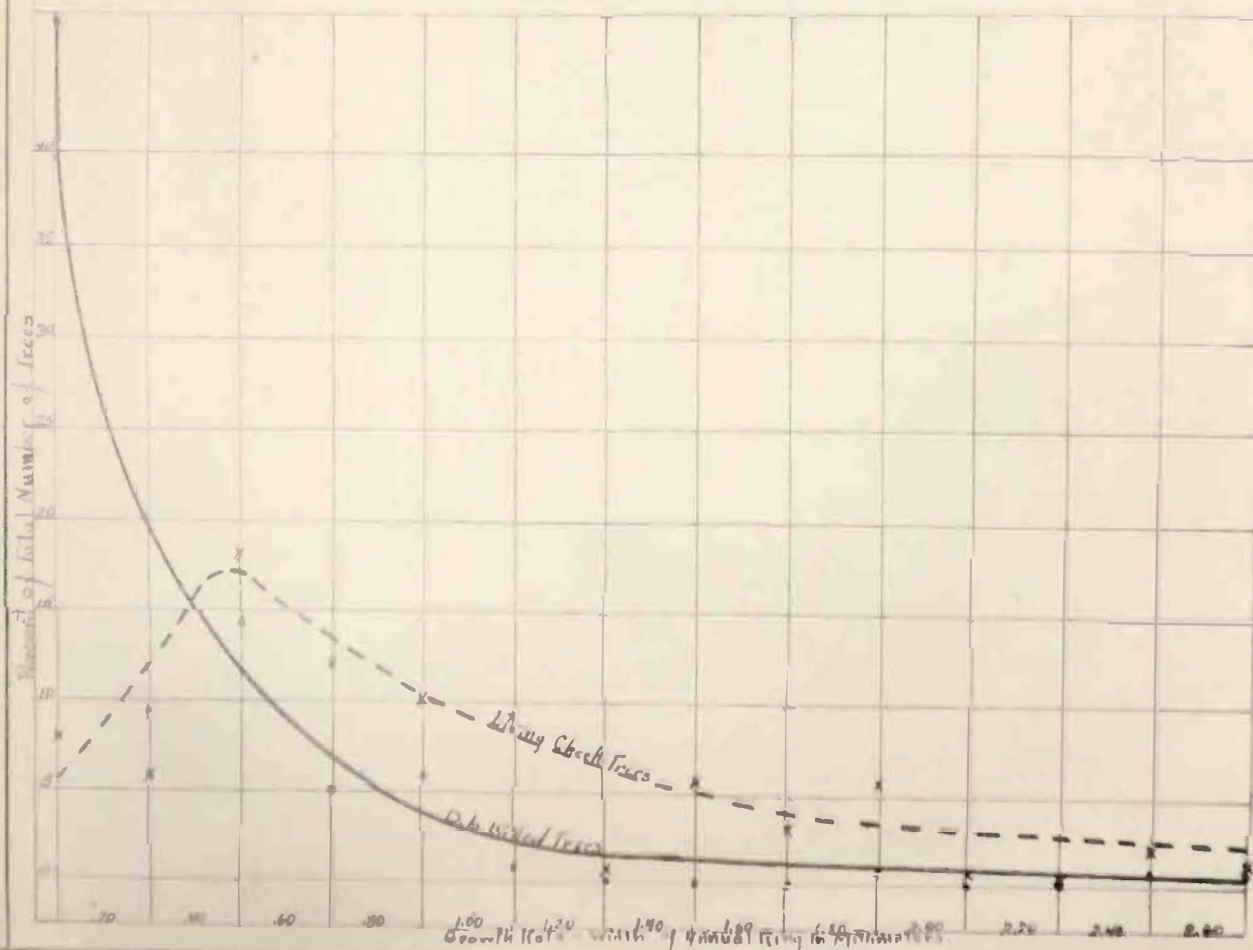
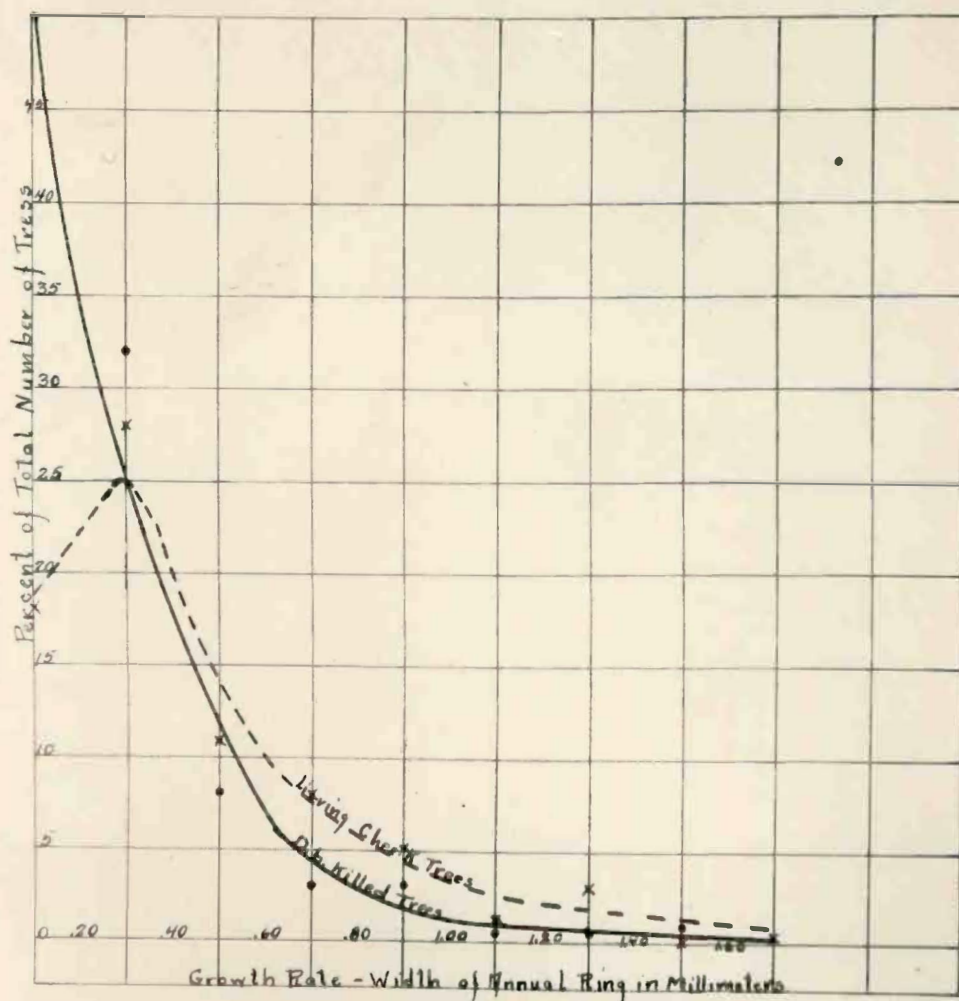


PLATE IX

Distribution by Growth Rate of D.b. Killed Trees & Living Check Trees.

Southern Oregon Area - D.b. Trees Killed 1924 - Basis 280 Cores.



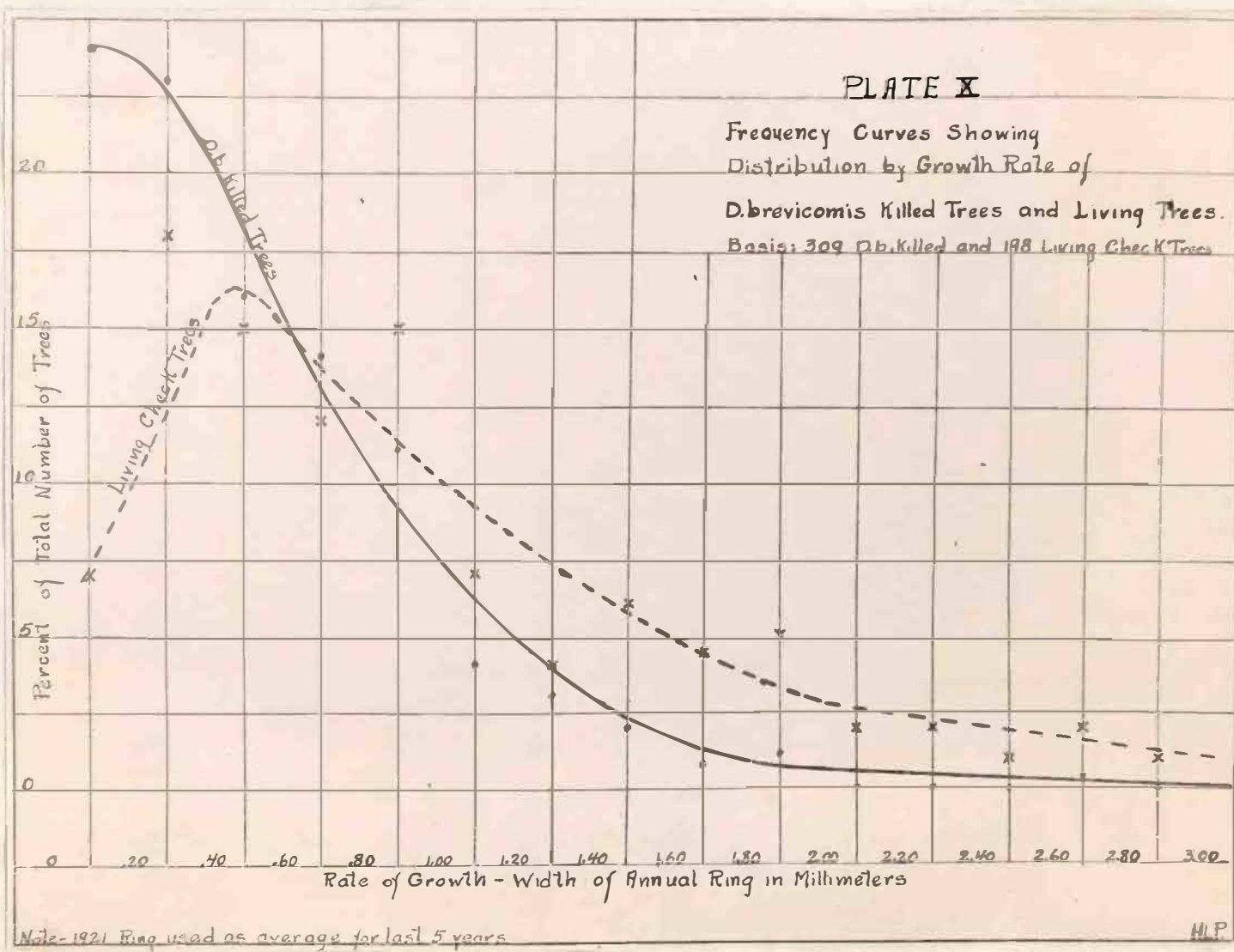


PLATE XI

Distribution by Growth Rate of D.b. Killed Tree & Living Trees
Basis-1936 Cores from California & Southern Oregon Areas.

